

DOCUMENT RESUME

ED 314 270

SE 051 128

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TITLE Nuclear Power: Time, Space and Spirit--Keys to Scientific Literacy Series.
REPORT NO ISBN-1-55979-011-3
PUB DATE 90
NOTE 37p.; This is one of a series of 16 booklets written with consultation from the History of Science Department at the University of Wisconsin-Madison. For other booklets in this series see SE 051 117-132. Drawings may not reproduce well.
AVAILABLE FROM Hawkhill Associates, Inc., 125 E. Gilman Street, Madison, WI 53703 (\$2.15 each, \$1.95 for 10 or more copies of the same title).
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Elementary Secondary Education; *Instructional Materials; Middle Schools; *Nuclear Energy; Nuclear Power Plants; Nuclear Warfare; Physics; *Reference Materials; *Resource Materials; *Science and Society; Science Education; Science History; Scientific Literacy; *Secondary School Science; Technology

ABSTRACT

One of the most important discoveries of the twentieth century was the fission of radioactive materials. This booklet considers nuclear energy from three aspects: time; space; and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters on the history and concepts of nuclear power, a time line related to these concepts, a map of the important geography related to these concepts, a glossary of important terms, and a list of several study suggestions are included. (CW)

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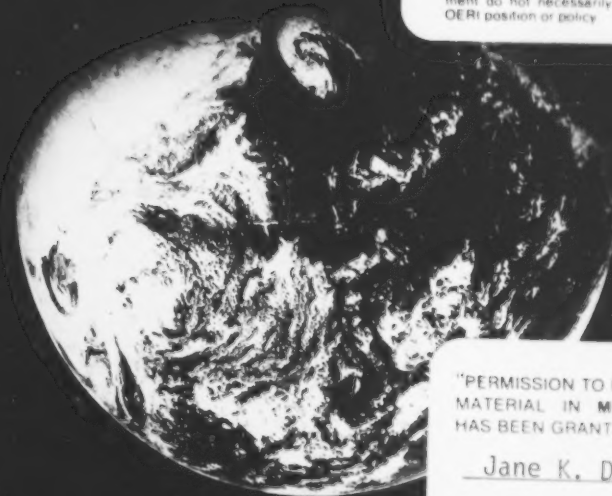
Nuclear Power

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A HAWKHILL LEARNING POWER BOOK

SE 051 128

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more—much more—in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this—the way this book follows—is to look at the world from three angles: *Time*, *Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles—*Time*, *Space* and *Spirit*.

Read on.

This book belongs to:

Nuclear Power

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit—Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit—Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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Printed in the United States of America

ISBN 1-55979-011-3

Hawkhill Associates, Inc., 125 East Gilman St.,
Madison, Wisconsin 53703

Part 1: The History of Nuclear Power



a beach in Normandy

On a beach in Normandy, France, thousands of Americans died on June 6, 1944. The Allied Expeditionary Force landed there, launching the final offensive that ended the long war against Nazi Germany, a worldwide catastrophe that claimed over forty million lives before it ended.

Five hundred miles away another little known drama was to prove as important as the bloody landing at Normandy. It happened in the narrow straits separating Denmark from Sweden.

Niels Bohr

To understand the full significance of this drama we need to go back a few decades and to meet a brilliant and kindly gentleman named Niels Bohr. During the



1920s and 1930s in his home town of Copenhagen, Denmark, Bohr was director of the world's most famous and productive center for studies of the atom. Many of the world's greatest scientists came here to study, to learn and to lay the foundations of what came to be called nuclear power. Bohr himself won the Nobel Prize in 1922 for his work in changing our picture of the atom. At that time, however, few realized the practicality, or the danger, of such power in peace or war.

visits Einstein at Princeton

In January of 1939 Bohr came to the United States to visit Albert Einstein at Princeton, New Jersey, and to attend a conference on theoretical physics in Washington, D.C. He brought with him startling news from Europe.



Hahn and Strassman in Germany

Lise Meitner, an outstanding Jewish physicist who had escaped Hitler's Third Reich, had recently told Bohr of some unusual new results her former colleagues Otto Hahn and Fritz Strassman were getting on experiments with the heavy element uranium. One radical interpretation of their



new data led Meitner and others to believe uranium could fission! That is, the nucleus of the atom itself could split apart—something never before observed—and in the process release incredibly large amounts of energy!

a theory of nuclear power

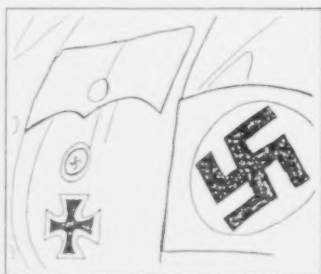
Within days of Bohr's news, three groups in the United States quickly confirmed the Hahn-Strassman data. Once confirmed, they immediately set to work—feverishly—to develop a theory to explain nuclear fission. And to develop a practical way to produce nuclear power.

U-235 needed

Bohr predicted correctly that only one particular kind of uranium—the uranium 235 isotope—would be capable of fission. But if enough of this rare isotope could somehow be obtained, theoretically at least, a bomb of almost unbelievable power could be built.

Nazi Germany conquers Europe

By the time Bohr returned to Denmark, World War II was heating up. Hitler attacked France and the low countries, occupying Denmark quickly in 1940. Bohr tried to keep his Institute open and do



what he could to save fleeing Jews, as well as continue his own research in secrecy.

Bohr escapes

He was ignored for a few years of the occupation. Then in the fall of 1943 (just as the Normandy invasion was being planned) Bohr made a daring escape across the narrow channel into Sweden. From there he was ferried in the gun turret of a bomber to England, almost dying from lack of oxygen during the flight.

Los Alamos, New Mexico

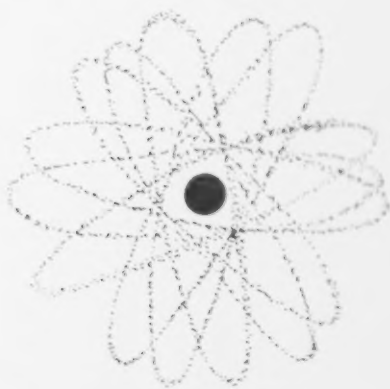
By the winter of 1944 he was working with other world-class physicists in top-secret government laboratories in Los Alamos, New Mexico. Many of these physicists were, like himself, in exile from their native countries. Some of the most famous included Enrico Fermi (from Italy), Edward Teller and Leo Szilard (from Hungary) and Hans Bethe (from Germany). The laboratory was headed by a famous American physicist, Robert Oppenheimer. Together they witnessed the world's first nuclear explosion on July 16, 1945.

Let's back up a little again and see in more detail just what scientific and technical steps were taken by these scientists, engineers and workers to get to that historic moment.

picture of the atom

Here is the picture of the atom put together by Thomson, Rutherford, Bohr and others during the early years of the twentieth century.

Every piece of matter in the universe is made of tiny atoms. Each atom has a structure of its own.



a tiny dense nucleus

In the center is an incredibly dense nucleus. This nucleus is made of a combination of two kinds of even smaller particles, protons and neutrons.

electron clouds

Most of the ordinary changes in our world are due to rearrangements of the electron clouds that buzz around that tiny nucleus.

radioactivity

The nucleus itself was supposed to be very stable, though the new work of Marie Curie and others had shown that for a few special kinds of atom, radium, for instance, the nuclear structure could change. It could be, they found, radioactive. That is, it could spontaneously disintegrate, changing itself into smaller atoms.

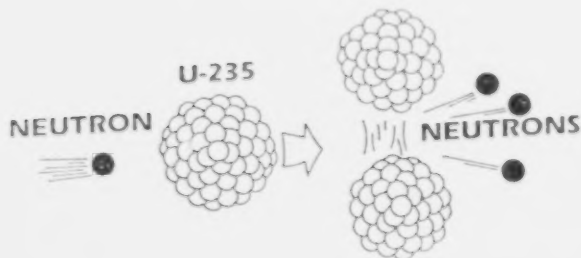


nucleus could split in two

The startling news from Germany showed that in the case of uranium at least, if that nucleus was hit by a slow-moving neutron, it would split in two! And in that cracking, it would release an enormous amount of energy. Energy far greater than any known chemical change.

with release of high energy

Not only did the U-235 nucleus give out enormous amounts of energy when it split, it also spit out at least two more neutrons. What if—the scientists asked—what if each of these newly created neutrons itself hit another uranium 235 atom? And what if these two split, and then the four



split and the eight and sixteen and thirty-two ... etc., etc.! Each of these doublings would release double and double and double the energy! The result would be a chain reaction that could indeed release energy the likes of which the world had never before seen.

Enrico Fermi

What could be done in theory was soon done in practice. The effort to actually make the first chain reaction happen was led by a refugee from Fascist Italy, Enrico Fermi.



the first nuclear reactor

What Fermi and his co-workers did was construct the first "nuclear pile" in a squash court under the former football stadium at the University of Chicago. It was called a "pile" in order to disguise its actual intent, though in truth it was a "pile" of graphite blocks, alternated with uranium and uranium oxide blocks.

a critical mass

Since only slow-moving neutrons would cause the uranium nuclei to split, the idea was to let the graphite blocks slow down the neutrons that were being spontaneously emitted by the fissioning uranium. These slower neutrons would then hit more uranium nuclei, causing them to "fission." This would release more neutrons which would hit more nuclei and if you had the right amount of fuel close enough together—what was called a *critical mass*—a chain reaction would result.

controlling the fission chain

It was critical in a nuclear reactor, as distinguished from a nuclear bomb, that the chain reaction be controlled. That is, it must not continue to multiply. To control it, Fermi's University of Chicago reactor had special cadmium control rods that could be raised and lowered to absorb neu-

trons, and thus adjust the number to a self-sustaining, but not a run-away, rate.

it worked

At 3:45 pm on Dec. 2, 1942 the nuclear pile at the University of Chicago did become self-sustaining. A telegram from the physicist Arthur Compton said it all, "The Italian navigator has entered a new world." Yes, Enrico Fermi and his co-workers had entered a new world as revolutionary as the one that earlier Italian, Christopher Columbus, discovered some 450 years before.



race for a bomb

Now that the new world had been discovered—in the middle of a world-wide struggle for survival against Nazi Germany, Fascist Italy and militaristic Japan—the race to produce a militarily effective bomb took precedence over all else.

Einstein writes to Roosevelt

Albert Einstein, long known for his pacifism, himself wrote a letter to President Roosevelt urging him to proceed with all due speed to develop an atomic bomb. Germany was now known to be working on such a bomb under the leadership of the famous physicist, Werner Heisenberg. Both

sides guessed correctly that it was only a matter of time before it could be done.

Oak Ridge, Tennessee

In the most stringent secrecy ever mounted in a free country, the United States did proceed with all due speed to construct gigantic research, development and production centers in Washington state, in New Mexico, and the largest of all, an entire new secret city in Oak Ridge, Tennessee.

separating U-235

At Oak Ridge over seventy-five thousand people were hired to build and operate the large factories designed to produce fission grade uranium that would be capable of making an nuclear bomb. Research had confirmed Bohr's prediction that it was only one particular isotope of uranium, U-235, that was capable of fission. Since naturally occurring uranium contains less than one percent U-235, the task of separating the two isotopes was formidable. Several methods were tried. In the end the method that worked best was called gaseous diffusion.

security at Oak Ridge

Security at Oak Ridge was extremely tight. All persons entering the city had to have identification. All had to have their cars checked and sometimes their persons searched. Except for a very few of the top scientists and engineers, no one working at Oak Ridge was given any information about the overall goal of the project. Workers were warned to say nothing at all about their work. Not in letters, not in telephone calls, not in person-to-person talk. Similar measures were taken at the Washington and the Los Alamos sites.

bomb is used in war

A little over two and a half years after the first chain reaction at the University of Chicago, the world's first nuclear bomb was exploded at Alamogordo, New Mexico. Just one month later, two bombs (the only other two then in existence) were dropped on Hiroshima and Nagasaki, Japan. Both

of these cities were destroyed. Over a hundred thousand Japanese citizens were killed. Japan surrendered and the most destructive war in human history was over.



nuclear weapons spread

Since that violent birth of the nuclear age, the science and the technology of nuclear power have advanced at a rapid pace worldwide. The United States had a monopoly in 1945 when the war ended, but very soon the Soviet Union and Great Britain (1949), France (1960), China (1964), and then India (1974), joined the nuclear nations in exploding their own nuclear bombs. Today it is believed that other nations such as Israel, South Africa and Pakistan also have nuclear capabilities.

As for peacetime uses of nuclear energy, every major nation on earth has built and now operates nuclear power plants.

hydrogen bomb tested

In 1952, led by the physicist Edward Teller, the United States for the first time exploded a fusion bomb, called a hydrogen bomb, thousands of times more powerful than the first fission nuclear bomb. Again, other countries successfully built and tested their own fusion bombs.

"Atoms for Peace"

In a speech on Dec. 7, 1953 (the 10th anniversary of the Japanese attack on Pearl Harbor) then-President Dwight Eisenhower proposed a new direction—what he called "Atoms for Peace."

uses in medicine and ecology

Many peaceful uses of nuclear energy were developed and are still being developed. In medicine especially, radioactive isotopes have become valuable



tools both for diagnosis and for treatment of many diseases, including cancer. In biological and ecological studies, radioactive tracers are used to discover much new information about the workings of living systems.

nuclear power grows

During the 1950s and 1960s nuclear power plants multiplied as the need for energy worldwide began to soar.

anti-nuclear protests also grow

Beginning in the 1970s and continuing today, there is a growing movement of dissent about nuclear power in peace as well as war.



**a good safety
record**

Although the nuclear power industry can point with pride to a remarkable safety record—as yet no known citizen fatalities in this country due to nuclear power accidents or failures—risks do exist and critics are not silent.

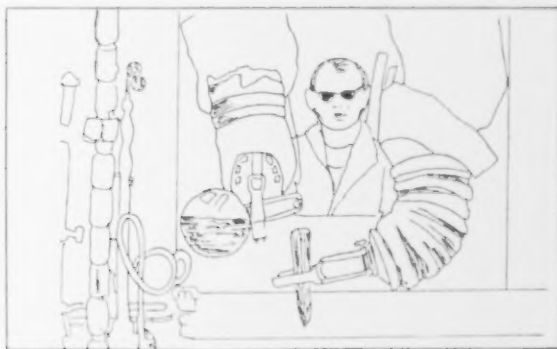
**dangers of
nuclear war**

Almost as soon as the first nuclear bombs exploded, many scientists directly involved in the research took leading roles in trying to alert the world to the dangers of nuclear war. And to the need for international control of these doomsday weapons.

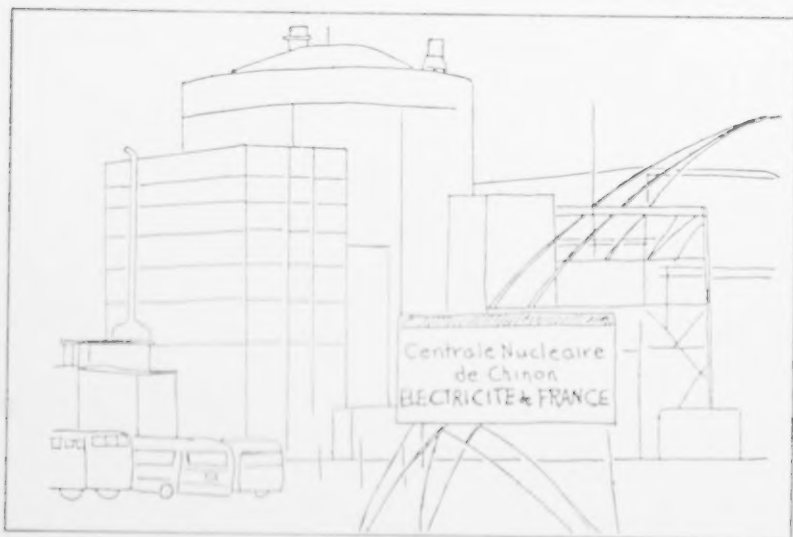
***Bulletin of the
Atomic
Scientists***

One of the most important of the publications founded to promote these goals has been the *Bulletin of the Atomic Scientists*, published monthly since 1945, and always with the same cover, the hands of a clock. Some months the hands point closer, and sometimes further away from midnight, that terrible day when the bomb would be used again in the ultimate catastrophe, nuclear war. (In 1989 the editors changed the face of the clock to an image of the globe, spaceship earth, reflecting a new urgency about environmental quality.)

Let's look at the current state of our knowledge and our controversies about nuclear power in Part 2 of this book.



Part 2: Nuclear Power, Today and Tomorrow



for and against nuclear power

"Better active today, than radioactive tomorrow ...
No nukes is good nukes."

"Nuclear power is the cleanest, safest and least expensive way to provide energy for our future."

Who do you believe? What do you believe?

values and facts

It's not easy. Especially in the present-day climate of heated debate. This book is not going to tell you what to believe, nor even to suggest that there is one right way to believe. What it can do is tell you what is presently known about nuclear power. And it can briefly outline the confusing mix of values and facts that will determine the future of nuclear power.

what is nuclear power?

First of all—just what is nuclear power? Notice I said nuclear power, not atomic power. Most of the sources of power in our world today—oil, coal,

atoms. This is the same source of power that our sun, and all the other stars, use to produce light and heat.

We know today that the world is made of a little over one hundred different kinds of elements. Each element has a unique number. They go from element number one, hydrogen, all the way up to the last naturally occurring element, number 92, uranium. Beyond uranium scientists have now made in the laboratory still heavier elements, at this writing all the way up to number 106.

1 H 2 He

3 Li 4 Be

5 Na 6 Mg

7 K 8 Ca 9 Sc 10 Ti 11 V 12 Cr 13 Mn 14 Fe 15 Co 16 Ni 17 Cu 18 Zn 19 Ga 20 Ge 21 As 22 Se 23 Br 24 Kr

25 Rb 26 Sr 27 Y 28 Zr 29 Nb 30 Mo 31 Tc 32 Ru 33 Rh 34 Pd 35 Ag 36 Cd 37 In 38 Sn 39 Sb 40 Te 41 I 42 Xe

43 Cs 44 Ba 45 La 46 Hf 47 Ta 48 W 49 Re 50 Os 51 Ir 52 Pt 53 Au 54 Hg 55 Tl 56 Pb 57 Bi 58 Po 59 At 60 Rn

61 Fr 62 Ra 63 Ac 64 Th 65 Pa 66 U 67 Np 68 Pu 69 Am 70 Cm 71 Bk 72 Cf 73 Es 74 Fm 75 Md 76 No 77 Lr

78 La 79 Ce 80 Pr 81 Nd 82 Pm 83 Sm 84 Eu 85 Gd 86 Tb 87 Dy 88 Ho 89 Er 90 Tm 91 Yb 92 Lu

93 Th 94 Pa 95 U 96 Np 97 Pu 98 Am 99 Cm 100 Bk 101 Cf 102 Es 103 Fm 104 Md 105 No 106 Lr

The atomic number tells how many positive charges the given atom has in its nucleus. This is the same as the number of proton particles. Hydrogen has the least possible number of protons, one. Uranium has the most naturally occurring number of protons, ninety-two. It turns out that nuclear power, for the most part, comes from rear-

ranging the nuclei of either the heaviest or the lightest of the elements.

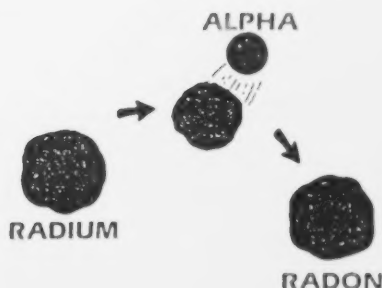
**uranium, a
radioactive
element**

Let's start with the heaviest, uranium. When elements get that large, the nucleus tends to be unstable. It tends to break apart spontaneously. This spontaneous breaking apart is called "radioactivity."

**radioactive
decay series**

When a heavy radioactive element, like uranium or radium, does break apart, it spits out a particle or particles from its nucleus and what is left is a

different element. The particles and rays emitted in the change are packed with high energy. The new element formed from this change is often itself radioactive. In turn it spits out more particles and still another new element is formed, again, often radioactive. In this way what is called a radioactive decay series



continues until we finally do reach an element like lead which is stable. At that point no further radioactivity occurs.

**varying times
to become
stable**

In some cases the series of changes happens in a matter of seconds. In other cases it takes years, even hundreds of thousands of years to get to the stable state.

**large energy
output**

At each stage of the decay process, large amounts of energy are also given off.

$$E = mc^2$$

This is the same energy that was formerly used to hold together the nucleus. Energy that can be calculated using Einstein's famous formula for the equivalence of energy and matter, $E=mc^2$.

background radiation

On earth, the number of atoms that are naturally radioactive is very small. Small in proportion, that is, to the total number of non-radioactive atoms. It may surprise you, though, to learn that in the air in an average living room or kitchen, there are at least ten or twenty billion radioactive atoms! This is not due to a nuclear weapon test, nor to a nuclear power plant. It is just the natural background radiation that so far as we know has been that way for millions of years past.

Let's move now into artificially created radioactivity, and into fission and fusion power.

isotopes

Besides the spontaneous disintegration of many heavy atoms, physicists discovered just before the second World War that some few particular isotopes of elements could fission. (Isotopes are forms of an element that have the same number of protons, but differing numbers of neutrons in the nucleus.)

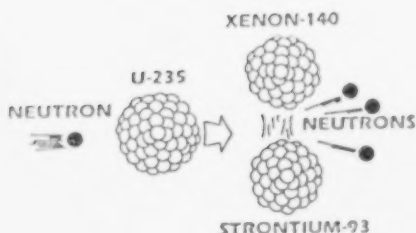
some isotopes can fission

Some of these isotopes of heavy elements break apart in a more radical way, splitting into two almost equal parts and giving out much more energy as well as two or more high-speed neutrons.

U-235 chain reaction

They also discovered that if they arranged these isotopes—notably uranium-235 (92 protons and 143 neutrons)—into the right geometry, a chain reaction would result.

One U-235, for instance, splits, giving off two neutrons and a lot of energy. These two neutrons each hit nearby U-235 nuclei and cause them to split. Each of these gives off two a piece and you quickly—very quickly—get four,



eight, sixteen, thirty-two, sixty-four, etc. etc. etc. And the reaction gets to very very high energy output.



controlling fission

If you arrange enough of the fissioning uranium in the right shape the chain reaction very quickly becomes an explosion. On the other hand, if you arrange them into another kind of shape, you can control the chain, and it does not explode. Instead it gives off a continuous supply of reliable heat that you can then use to boil water and run electrical generators. This is what happens in a nuclear power plant.

differences

It needs to be emphasized that although the two cases are similar in some ways, they are totally different in others.

Both rely on the energy from chain reactions of either uranium or the artificially created plutonium. However, the construction being very different, there is no chance at all that a nuclear power plant could explode like a nuclear bomb.

accident risk

The high tolerances and the exposure to very difficult corrosion problems of pipes, valves and other equipment—as well as the potential for serious human operator error—do lead to the possibility



for serious accidents however. Accidents in which dangerous amounts of radioactive elements could escape the reactor building and be spread by wind and water through nearby communities, causing serious harm to humans

and other living things in the biosphere. Not only immediately but for years or even centuries to come. This is because one of the harmful effects of radiation can be genetic damage which is carried over into future generations.

Chernobyl accident

The most serious nuclear power accident in the world happened at Chernobyl in the Soviet Union on April 26, 1986. Thirty-one workers at the power plant died in the accident. Over 100,000 people were evacuated from their homes in an eighteen-mile radius around the plant. Radioactivity levels of soil, air and water in this area are still substantially above accepted safety levels so that many of these people will not be able to return for some years to come. In addition, radiation experts estimate there will probably be an additional one to two hundred deaths among the most severely exposed from radiation-caused cancer in the next few decades.

genetic effects

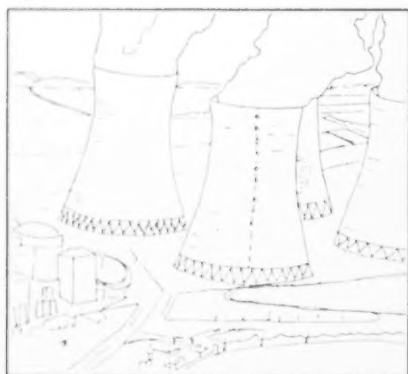
Since genetic effects take longer to observe, one can never be sure. So far the signs are hopeful. Especially since the results from studies done on the survivors of the much worse nuclear catastrophes at Hiroshima and Nagasaki, Japan, over forty

years before, are now coming in. So far these studies show a surprising lack of genetic effects.

radioactive fall-out

Radioactive materials from the Chernobyl meltdown were carried by winds over much of northern Europe, small amounts even reaching into the western hemisphere and the United States. There is some dispute among experts today, but the vast majority agree that so far there seem to have been no harmful effects in people, plants or animals from this fall-out radiation.

Three Mile Island



The most serious accident in this country was at Three Mile Island near Scranton, Pennsylvania in 1969. Fortunately there were no fatalities here, nor as yet any health effects to people living nearby. In fact the total amount of additional radioactivity in the near vicinity of Three Mile Island in the weeks immediately following the accident was not as great as you would get on one transatlantic airplane flight.

no new nuclear plants in U.S.

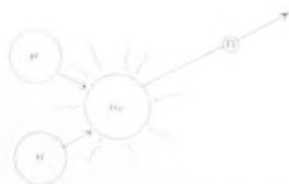
The United States in 1989 gets over twelve percent of its electricity from nuclear power plants. Because of increasing public fear, no new nuclear power plants have been ordered in the United States for some years now. However in other countries nuclear power plants continue to be built and to provide an increasing proportion of the world's electricity.

new designs

Experience from the accidents has also led to new designs and added safety features on new reactors that will make future accidents increasingly unlikely.

energy from fusion

This is nuclear power from the fissioning of heavy atoms. There is also nuclear power from the fusing of very light atoms. One isotope of hydrogen,



for example, has two extra neutrons in its nucleus. Under certain intense circumstances it can fuse together with another hydrogen to make helium, element number two. In this process even larger a-

mounts of energy are given off than in fission. Hydrogen fusion is the basic source of energy that was tapped in the first hydrogen bombs. It is also the basic source of energy in the sun and stars.

Though a great deal of research and development has already been done, we still have not developed a practical way to tame the fusion reaction and to produce nuclear fusion power plants.

the ideal energy source?

Many researchers think that once we do this—and few doubt that it will eventually be done—the world will move toward fusion nuclear power as its first energy choice of the future. Not only could it produce abundant and cheap energy, it could produce this energy with few, if any, of the disadvantages of fission plants. Fusion power plants, for instance, would have much more manageable waste problems. Unlike fission, the fusion reaction itself produces no radioactivity. Fusion reactions are so intensely powerful that great economies could be made in providing energy for the greatest number of people at the least cost.

two kinds of power

Let's sum up now. There are two kinds of events that produce energy and power in our world.

atomic power

One is atomic power. This is the kind of energy and power we get from rearranging the electron

shells of atoms. The kind of power we get from burning wood, coal, oil, gas and gasoline. The kind of power we get from burning food in our own muscle cells.

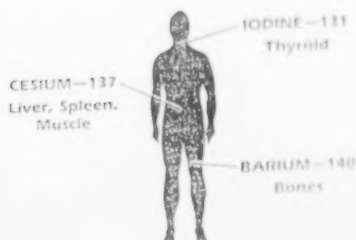
nuclear power

The second kind is nuclear power. This is the kind of power we get when heavy atomic nuclei fission—that is, split apart. And the kind of power we get when light atomic nuclei fuse—that is, join together.

Nuclear reactions can be used in an uncontrolled way to produce a nuclear explosion. They can also be controlled in a different kind of structure to produce electrical power.

radiation can be harmful and helpful

Nuclear reactions produce radiation that is potentially harmful to living tissues. Diagram below shows a few of the most common problems. Radiation can also damage genes, and thus effect future generations. This



same radiation, in appropriate doses, can also be used in many helpful ways. It can be and is used to help diagnose diseases, destroy cancer cells, trace toxic waste flows and help solve many thousands of

baffling environmental and scientific problems.

half-life

The radiation produced by nuclear power consists of invisible high-speed particles and rays. Some radioactive elements produced by nuclear explosions and nuclear power plants are short lived, others are extremely long-lived. The most common measure of how long they will remain radioactive is called the *half-life*. A half-life of ten years means that in ten years half of the radiation will be gone. Ten years later you have only a fourth as much radiation. Etc. Etc. Half-lives

range from fractions of a second to hundreds, thousands or even millions of years.

With this background of history and fact, let's conclude with a brief look at the present-day debate about nuclear power's present and future.

anti-nuclear arguments



Considering the dangers, one extreme view would be to attempt by education, legislation and public pressure and protests to totally shut down all nuclear power plants, all nuclear research and destroy all existing nuclear bombs. We should make all the world a nuclear-free zone. "No nukes is good nukes." If we cannot do this immediately, we should move in that direction as fast as humanly possible.

pro-nuclear arguments

Considering the potential, the opposite view would be to rush full-scale into a more effective and accelerated nuclear power program in order to provide cheap energy for all the world's people, and at the same time to accelerate development of new nuclear weapons technology so as to effectively deter war and promote human freedom. And if we cannot do all this immediately, the sooner the better.

No doubt most people today would find their own views somewhere in between these two extremes. To help you understand the extremes as well as the in-betweens, let's take a look at some of the reasoning behind both.

nuclear wastes

On the side of the dangers, we would have considerations like the following. The wastes from nuclear power plants and bomb factories is packed with intensely dangerous radiation. Biologists and geneticists tell us there is no lower limit

to the danger to living things from radiation. Every little bit potentially hurts and can kill. We are producing radiation now that will last for thousands of years into the future. It is foolish to think humans can be trusted to keep anything in safe deposit for that length of time. We are bequeathing terrible time bombs to future generations.

possibility for accidents

An accident at a nuclear power plant (note Chernobyl and Three Mile Island) would be a far worse catastrophe than anything we have hitherto been faced with in human history. Thousands of people, maybe millions, would be exposed to dangerous radiation for years, for centuries to come. Not to mention other living things.

nuclear war

Worst of all would be a nuclear war which no one could win and which could bring about the destruction of the human race. Indeed the fatal poisoning of the planet itself for any kind of life. Getting rid of these potentially catastrophic power plants and these insanely destructive weapons once and for all is the only rational alternative to species suicide.

good safety record

On the side of the potential we would have considerations like the following. The nuclear industry—despite Three Mile Island and Chernobyl—has one of the best safety records of any industry ever



created by human beings. There is no reason to suppose we cannot continue to improve our designs and our safeguards and to prevent catastrophes such as opponents imagine. We cannot choose to have no risks in this life. The wise person chooses the path with the most po-

tential for good and the least risk for harm. That is the case with nuclear power.

**comparing
risks**

There may be no lower absolutely safe limit of radiation, but few people realize that you get over a thousand times more radiation watching TV, or just living in a brick house than you would get living next door to a nuclear power plant. The accident at Three Mile Island caused radiation immediately surrounding the plant that was only a third of what you would get on a commercial jet flight from coast to coast. Chernobyl was indeed worse, but even here many fewer people died or were hurt than in many hundreds of other accidents in recent years due to reliance on conventional sources of power such as coal, oil and gas.

**coping with
wastes and
threats of war**

Contrary to critics, we already have quite a few safe and effective ways to dispose of radioactive wastes. And remember, a nuclear plant produces less radioactive waste in the air, soil and water than a presently operated coal-fired plant. In addition, nuclear plants do not contribute to acid rain or the greenhouse effect.

It is true that a nuclear war would be a very great human catastrophe, perhaps even the ultimate human catastrophe. However, it is naive and self-defeating to imagine you can prevent this by total (and especially by unilateral) disarmament. Such a path would itself lead to the very highest risk of bringing on what you want to prevent.

**use reason,
not slogans**

The newspapers, the television specials, the books and pamphlets (including this one) are all bombarding us with information, rhetoric and reasoning on these issues. Take it on yourself to investigate as carefully and fairly as you can. Don't let slogans make up your mind. Study all sides of the issue and come to your own conclusion, like any other scientist would.

TIME ...

To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.

EVENTS IN WORLD HISTORY

1914-18
World War I

1939-45
World War II

1950-53
Korean War

1966-73
Vietnam War

1900

1950

EVENTS IN SCIENCE & TECHNOLOGY

1900

1895-1910
x rays, radioactivity
discovered

1922
Bohr wins Nobel Prize for
theory of atom

1938
Hahn & Strassman report
fission of uranium

1945
first nuclear bombs

1953-1970
rapid growth of nuclear
power industry

1970-present
anti-nuclear protests and
debates

1983
Three-Mile Island accident
1986
Chernobyl nuclear power
accident

1950

SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you to locate the important events and people discussed in this book.



**1. Normandy,
France**

Where the Allied Expeditionary Forces landed in 1944, launching the offensive that defeated Nazi Germany in the Second World War.

**2. Hiroshima and
Nagasaki,
Japan**

Where the first nuclear bombs were used in warfare, destroying these two Japanese cities. A week later the Japanese surrendered, ending the Second World War.

**3. Chernobyl,
USSR**

Site of serious nuclear power plant meltdown in 1986.

**4. Three-Mile
Island,
Pennsylvania**

Site of nuclear power plant accident in 1983. A partial meltdown.



**1. Alamogordo,
New Mexico**

Where the first nuclear explosion happened on July 16, 1945.

**2. Chicago,
Illinois**

On December 2, 1942, the nuclear age began when a team of physicists led by Enrico Fermi achieved the first self-sustaining nuclear fission reaction. It happened in the squash court under the University of Chicago football stadium.

**3. Oak Ridge,
Tennessee**

Where the fissionable isotope of uranium, U-235, was first produced by the gaseous diffusion process for the world's first nuclear bombs.

**4. Hanford,
Washington**

Site of large nuclear plant built during World War II to produce materials for the first nuclear bombs.

**5. New York, New
York**

Site of the United Nations where President Dwight Eisenhower first proposed "Atoms for Peace."

SPIRIT ...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things—connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit worked in the past—and are working today.

atom	What the world is made of. The smallest unit of every element.
atomic number	The number of protons in the nucleus of an atom. See periodic table of elements. (p. 13)
Bohr, Niels	One of leading physicists of twentieth century. Won Nobel Prize in 1922 for his work on atomic theory. (p. 1-4)
chain reaction	A self-sustaining nuclear reaction in which each fission (or fusion) of an atom causes more fission (or fusion). (p. 5-7, 15-16)
Chernobyl	Site of a nuclear accident in the USSR in which thirty-one people were killed and hundreds of people injured in 1986. (p. 17-18, 25)
critical mass	In nuclear reactors or bombs, the amount of fissionable fuel needed to create a chain reaction. (p. 7)
Curie, Marie	Polish-born scientist who discovered the element radium and advanced the study of nuclear physics and chemistry. (p. 5)
Einstein, Albert	Leading physicist of twentieth century who discovered theory of relativity. (p. 2, 8, 14)
$E = mc^2$	Einstein's formula for the equivalence of matter (m) and energy (E). (c) stands for the speed of light. (p. 14)
electrons	Negatively charged particles in the atom. The basic particle in electricity and electronics. (p. 5, 13)

Fermi, Enrico	Italian physicist who led the team that produced the first working nuclear reactor at the University of Chicago in 1943. (p. 6-7)
fission	The breaking apart of an atomic nucleus. (p. 3, 5-7, 14-16)
fusion	The joining together of atomic nuclei to make a larger atomic nucleus. (p. 10, 19)
genetic	The passing on of traits from parent to offspring. (p. 17-18, 22)
half-life	A way of measuring how long an isotope will remain radioactive. A half-life of ten years means that in ten years half of the material will no longer be radioactive. Ten more years radioactivity again cut in half, etc. (p. 20-21)
hydrogen	The simplest atom, number one on the periodic table, with one proton and one electron. (p. 13, 19)
hydrogen bomb	A nuclear bomb that uses the fusion of hydrogen as its source of power. (p. 10, 19)
isotopes	Varieties of the same atom with different numbers of neutrons in their nucleus. (p. 3, 8, 10, 15)
meltdown	A serious accident in a nuclear power plant where the temperature gets high enough to melt the radioactive fuel. Happened at Chernobyl. A partial meltdown at Three Mile Island. (p. 17)
neutrons	Particles with no charge in the nucleus of atoms. (p. 4-7, 15-16)
nuclear	A reaction involving changes in the nucleus of atoms that releases large amounts of energy. An uncontrolled reaction is a nuclear bomb, a controlled one in a nuclear reactor.
plutonium	Element number 94. Created in nuclear fission and itself fissionable. (p. 13)

protons	Positively charged particles in the nucleus of an atom. (p. 4, 13, 15)
radiation	Energetic particles or waves. Sunlight is one example of radiation. The potentially harmful rays and particles from radioactive materials are others. (p. 14, 17-18, 20-23)
radioactive wastes	Wastes from nuclear reactors or explosives that are potentially harmful to living tissues. (p. 20-23)
Teller, Edward	Hungarian-born physicist called "father of the H-bomb." (p. 4, 10)
U-235	The isotope of uranium that can fission and thus be used in bombs and reactors. (p. 3, 5-8, 15)
uranium	Element number 92 on the periodic table. (p. 3, 5-8, 13, 15)

In addition to the above, *Nuclear Power* also teaches about other important people, places, things, and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following words. For help, check the pages listed in this Learning Power Book, or if necessary, a dictionary or encyclopedia:

background radiation (p. 15); *Bulletin of Atomic Scientists* (p. 11); Eisenhower, Dwight (p. 10); Fascist (p. 8); graphite (p. 4); Hahn, Otto (p. 2); Heisenberg, Werner (p. 8); Hiroshima, Japan (p. 9); Meitner, Lise (p. 2); Nagasaki, Japan (p. 9); Nazi Germany (p. 1, 3); Nobel Prize (p. 1-2); Oppenheimer, Robert (p. 4); Pearl Harbor (p. 10); periodic table of the elements (p. 13); radium (p. 5); Roosevelt, Franklin (p. 8); Strassman, Fritz (p. 2); Three Mile Island (p. 18).

STUDY SUGGESTIONS ...

1. The high hopes of two decades ago for cheap, non-polluting energy from nuclear power have plummeted in recent years. In this country, that is. Many other countries are moving rapidly toward more nuclear power. At a 1989 World Energy Conference in Montreal, Canada, the great majority of world energy experts attending called for a huge shift to nuclear power in order to cure the greenhouse effect. Investigate and debate the future of nuclear power worldwide.
2. Albert Einstein has always been the most well-known scientist of the twentieth century. He was also a well-known pacifist. Investigate and discuss the implications of his famous letter to President Roosevelt urging him to proceed with research and development of nuclear weapons.
3. There are many fascinating personal stories about famous scientists who contributed to the development of the nuclear bomb. Any one or more of the names mentioned in this book would make an interesting subject for library research.
4. This program can only touch the surface of current debate about nuclear disarmament and nuclear power prospects. Whatever opinion you have now about these issues, take the time to read articles and books on a different side of the issue. Write a short report summarizing your findings. Did you change any of your opinions?

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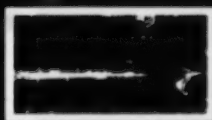
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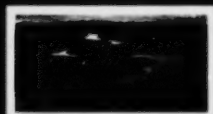
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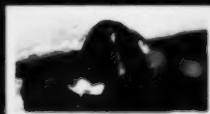
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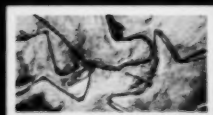
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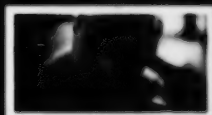
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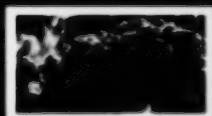
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